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Development and thermal requirement of *Anthocoris minki pistaciae* (Hemiptera: Anthocoridae) at different temperatures

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Abstract: The common pistachio psylla, *Agonoscena pistaciae* Burckhardt and Lauterer (Hemiptera: Psylloidea), is considered as the most destructive pests of cultivated pistachio trees in Iran. The predatory bug, *Anthocoris minki pistaciae* Wagner was found as a biocontrol agent for *A. pistaciae* in pistachio plantation areas of Iran. The influence of temperature on development of this predatory bug was studied at eight constant temperatures ranging from 17.5 to 35℃ and under controlled condition (55% ±5% R. H. and 16L:8D), while rearing on nymphs of *A. pistaciae*. The results showed that the predator develops successfully within a wide range of temperature 17.5 - 32℃, however the eggs almost failed to hatch at 35℃ and only 10% of bug's nymphs reached to adulthood at 35℃ too. The shortest developmental time was obtained at 30℃ from egg to adult emergence. The thermal constants for development of egg, nymph and total development (egg to adult) for this predatory bug were estimated to be 77, 200 and 263 degree-days, respectively. The lower thresholds for egg, nymph and overall development were found to be 8.53, 9.2 and 9.47℃, respectively. These results provide valuable information to develop an integrated pest management program for the common pistachio psylla.

Key words: *Agonoscena pistaciae*; *Anthocoris minki pistaciae*; developmental duration; lower developmental threshold; pistachio

1 INTRODUCTION

The common pistachio psylla, *Agonoscena pistaciae* Burckhardt and Lauterer (Hemiptera: Psylloidea), the key pest of pistachio trees (*Pistaciae vera* Linnaeus) is distributed throughout pistachio-producing regions in Iran. This pest is present from mid-March until early December on pistachio trees and has five to six generations per year. The presence of large populations of psyllid nymphs and adults causes severe problems in kernel development, causing bud drop and defoliation. Therefore, it causes severe reduction in pistachio yields for 3 consecutive years (Mehrnejad, 2003). The common pistachio psylla occurs in many pistachio growing regions in Asia Minor and the Middle East, as well as in Mediterranean regions (Burckhardt and Lauterer, 1989, 1993; Mart *et al.*, 1995; Lauterer *et al.*, 1998). This pest has been controlled almost exclusively by pesticide; however, many populations of *A. pistaciae* have developed resistance to various insecticides (Mehrnejad, 1998). Therefore, some alternative techniques to manage this economical pest, such as biological control are necessary. Information on the status of most psyllid's natural enemies in pistachio-growing areas of Iran has been summarized (Mehrnejad and Emami, 2005). According to them, the predatory bug, *Anthocoris minki pistaciae* Wagner was reported as a biocontrol agent of *A. pistaciae* (Mehrnejad and Emami, 2005). Therefore, knowledge of this predator adaptation to climatic factors plays an important role in their mass rearing and activation. Of all the ecological factors, the temperature is a critical abiotic factor influencing the dynamics of pest's natural enemies (Rosen and Huffaker, 1983; Nechols *et al.*, 1999).

The aim of this work was to estimate the developmental time and survival rate of immature stages of *A. minki pistaciae* at eight different constant temperatures as a preliminary step to evaluate its

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effectiveness as a biological agent for controlling *A. pistaciae* at different climatic regions of Iran.

2 MATERIALS AND METHODS

2.1 Insect culture and experimental condition

Predatory bugs used in the present study, were collected from pistachio trees in Rafsanjan (South-western part of Iran). *A. minki pistaciae* stock culture was performed in a laboratory under the condition of 27.5 ± 1℃, 60% ± 10% R. H. and a photoperiod of 16L∶8D. The colony was fed on nymphs of *A. pistaciae* and the pistachio leaf-discs were used as an oviposition substrate. Leaf-discs were placed into Petri dishes (52 mm diameter) that contained agar medium as the moisturizing source. Then leaf-disc cages were introduced in a plastic box (25 cm × 17 cm × 10 cm), having a hole (4 cm) covered by nylon screen for ventilation. Relative humidity was regulated by placing saturated 'magnesium nitrate' salt inside the box. The nymphs of *A. pistaciae* used in our investigation, were daily collected from pistachio orchards in Rafsanjan, and were served for the predators feeding.

2.2 Development and survival of *A. minki pistaciae*

The effects of temperatures on developmental period and survival of the egg and nymphal stages of *A. minki pistaciae* were calculated in growth chamber at eight constant temperatures, including 17.5, 20, 22.5, 25, 27.5, 30, 32.5 and 35℃, R. H. 50% – 60% and a photoperiod of 16 h∶8 h (L∶D). The cohort eggs of the predator were obtained from the stock colony and incubated at the eight above mentioned temperatures. Egg development was checked every 24 h and hatchability was calculated by dividing the numbers of eggs hatched by the numbers of eggs deposited. To study the developmental time and survival of the nymphal stage, a newly-hatched nymph was introduced into a leaf disc cage, at 30 replications. The cages were checked every 24 h and the nymph's moulting status or mortality was recorded until maturity.

The mean developmental rates of this predator at all temperatures were fitted to a nonlinear development model. Temperatures in the mid-range of the polynomial curve (linear area) were selected and used to fit a linear regression. The equation of linear regression ($y = a + bT$) was used to predict the T_0 and K, using Campbell *et al.* (1974) formula.

3.2 Statistical analyses

The data was analyzed using the MINITAB statistical program (MINITAB, 2000). Analysis of variance (ANOVA) was used to test the differences in all experiments. Mean comparisons were performed using LSD-tests at the 0.05 level.

3 RESULTS

The developmental time of all stages of *A. minki pistaciae* at eight constant temperatures are presented in Table 1. In general, the developmental time was decreased by increasing the temperature from 17.5 to 30℃ and then was increased at 32.5 and 35℃. The shortest developmental time for the egg and nymphal stages were observed at 30 and 32.5℃, respectively (Table 1).

The egg hatchcbility ranged from 18.8% to 86.5% at temperatures between 35 and 17.5℃, respectively. The survival rate of nymphs was considerably high at 22.5℃ (80%) and subsequently was decreased to 10% as temperature further increased up to 35℃ (Fig. 1).

The linear and third-order polynomial models for describing the relationship between temperature and developmental rate for the egg, nymph and total development are shown in Fig. 2. The third-order polynomial regression was used for fitting the data of developmental rate for the predatory bug. The coefficient of determination (R^2) ranged from 0.986 to 0.993 at egg and adult stages, respectively (Fig. 2).

Table 1 Developmental time (d) for different stages of *Anthocoris minki pistaciae* fed on *Agonoscena pistaciae* at different constant temperatures

Stage	Temperature (℃)							
	17.5	20	22.5	25	27.5	30	32.5	35
Egg	7.85 ± 0.09 a	6.67 ± 0.06 b	5.4 ± 0.09 c	4.14 ± 0.04 de	4.08 ± 0.06 d	3.8 ± 0.07 e	4.3 ± 0.04 f	4.23 ± 0.08 df
Nymph	19.8 ± 0.38 a	19.35 ± 0.22a	14.21 ± 0.16 b	11.04 ± 0.15 c	10.82 ± 0.2 dc	10.52 ± 0.12 ed	10.28 ± 0.1e	13 ± 0.6 f
Total	27.98 ± 0.4 a	25.75 ± 0.22 b	19.61 ± 0.16 c	15.3 ± 0.15 d	14.79 ± 0.19 ed	14.38 ± 0.12 e	14.58 ± 0.1e	17.23 ± 0.58 f

Means ± *SE* followed by different letters in the same row are significantly different ($P < 0.05$, LSD-test).

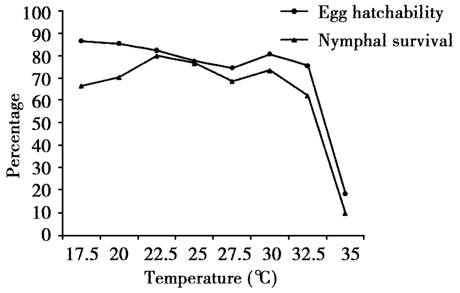

Fig. 1 Egg hatchability and nymphal survival of *Anthocoris minki pistaciae* at eight constant temperatures

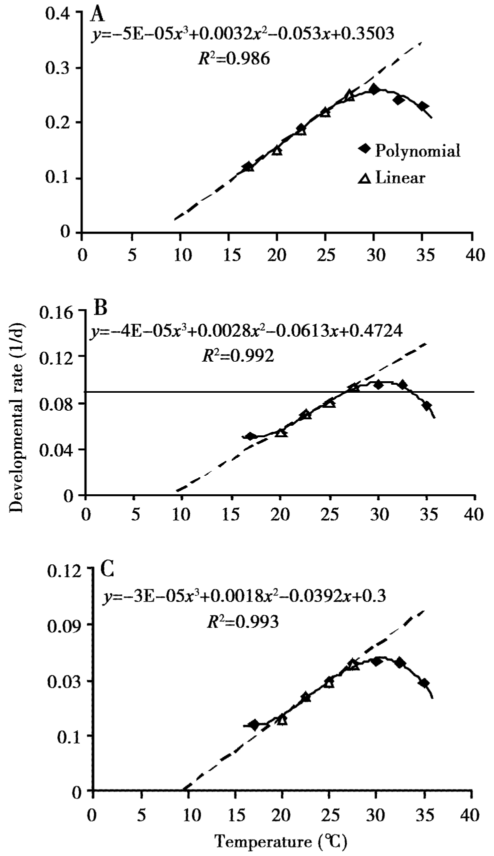

Fig. 2 Relationship between temperature and developmental rate of *Anthocoris minki pistaciae* at different constant temperatures

A: Egg; B: Nymph; C: Egg to adult.

Regression equations and determination coefficients are listed in Table 2. All developmental rates were significantly fitted to linear regression. The lower threshold temperature was obtained for egg and the other stages were very close to each other. It was the lowest at the egg stage (8.53℃) and the highest at the egg to adult stage (9.47℃). On average 263 degree-days were needed to complete immature stages.

Table 2 Linear regression of developmental rate of *Anthocoris minki pistaciae* at eight constant temperatures

Stage	T_0	K(DD)	Regression	R^2	P-value
Egg	8.53	77	$Y = 0.097 + 0.012X$	0.995	0.000
Nymph	9.2	200	$Y = 0.046 + 0.005X$	0.992	0.004
Total	9.47	263	$Y = 0.036 + 0.0038X$	0.992	0.004

R^2 = Coefficient of determination; T_0 = Lower developmental threshold (°C); K = Thermal constant.

4 DISCUSSION

No other study has covered the effect of temperature on development, survivorship and thermal requirements of *A. minki pistaciae*. The results reported here showed a clear influence of temperature on developmental time and survival rate of *A. minki pistaciae*. The bug was developed successfully over a wide temperature range from 17.5 – 35℃. The developmental period was rapid between 25 and 32.5℃. The lowest developmental time was observed at 30℃, so this temperature seems to be the optimal temperature for immature development. On the contrary, the eggs' developmental time for *Orius strigicollis* (Popoius) fed on *Frankliniella occidentalis* (Perdande) were recorded as 6.5, 4.5 and 3.1 d at rearing temperatures of 20, 25 and 30℃, respectively (Ohta, 2001), which was approximately similar to our results. Our results are very similar to those obtained by Nakashima and Hirose (1997) who studied the influence of temperature on development of immature stages of *Orius tantillus* (Motschulsky), as a biocontrol agent of *Thrips palmi* Karny. According to their findings, the eggs' developmental time was calculated to be 4.14, 3.9, 3.2 and 4 d at 25, 27.5, 30 and 32.5℃, respectively. That was so close to our estimates. At a similar experiment, developmental time for the nymphs of *Anthocoris nemorum* (L.), *A. nemoralis* (F.), *A. sarothamni* Douglas and Scott, *A. gallarum ulmi* (DeG.), *A. confusus* Reut. and *A. minki* Dohrn fed on different species of aphids at 23℃ was recorded by Anderson (1962). The nymphal developmental time was 14.21 d at 22.5℃ in current study, which is very approximate, for *A. nemoralis* and *A. sarothamni* (14.9 d) but was considerably shorter for *A. nemorum* (23.7 d). These differences are likely related to different predator and prey species. The percentages of egg hatchability and nymphal survival were considerably decreased at the highest extreme of temperature (35℃), while at 35℃, about 90% of nymphs were dead. To compare, our results are different from those obtained by Ohta (2001) who studied the influence of temperature on these two parameters for the immature stages of *O. strigicollis*. According to his findings, the survival percentages for nymphs were estimated to be 55.3, 65.5 and 37.3 at 20, 25 and 30℃, respectively. These values are all lower than those of *A. minki pistaciae*. On the other hand, the hatchability was higher than 90% from 20 to 30℃, which was also different from our findings in this study.

The linear regression equations showed a positive relationship between the developmental rate and temperature at all immature stages. Furthermore, according to R^2 values for linear and nonlinear regression equations, the correlation between developmental rate and temperature was high ($R^2 = 0.99$). The highest value of R^2 for the adult stage, using third order polynomial regression curves, showed the best fitness of the model at this stage.

The lower temperature threshold for immature development was 9.47℃ that differs a little from Hofsvang (1976) and Shima and Hirose (2002) who reported 10.6℃ and 9.6℃ as a threshold temperature from egg to adulthood for *Anthocoris sibiricus* Reuter and *Wollastoniella rotunda* Yasunaga *et* Miyamoto, respectively. To the contrary, Ohta (2001) reported that *O. strigicollis* needs 57.5 and 158.7 degree-days for completing egg and nymphal stages, respectively. That was considerably lower than those of *A. minki pistaciae*. As well as the differences occurred for lower temperature threshold at egg and nymphal stages (11.5 and 11℃, respectively). These differences may be due to different host species and experimental conditions. Similar results were conducted by Askari and Stern (1972), and Kingsley and Harrington (1981) for *Orius tristicolor* (white) and *Orius insidiosus* (Say), respectively. In another investigation which was done by Mehrnejad (1998) on development and thermal requirements of *A. pistaciae*, the surprising result was obtained that the lower thermal threshold and thermal constant at egg to adult stages was relatively close to our data (10.7℃ and 238 degree-day). So our results indicated a relative potential synchronization between predator and prey. Therefore, we can predict that this prey species can be a suitable candidate for serving as the food source for predator mass rearing in our tested region. Additionally, according to our data *A. minki pistaciae* is well adapted to the low temperatures. So in cooler temperatures in early spring, the predator will develop a very small population, before increasing of psyllid populations. Knowledge of the predatory feeding behavior in the absence of prey is limited and needs more investigations.

This work described the development-temperature and thermal requirements of Rafsanjan population of *A. minki pistaciae* under a broad range of temperature. Nevertheless, more information about the influence of untested temperatures and other biotic and abiotic factors, such as humidity, photoperiod and prey species adaptation in pistachio gardens in different parts of Iran would be important for introducing this predator as a potential biocontrol agent of psyllids.

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锈褐原花蝽在不同温度下的发育与积温必需条件

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摘要: 阿月浑子树木虱 *Agonoscena pistaciae* Burckhardt and Lauterer (半翅目: 木虱总科)是伊朗园林树木阿月浑子树上常见的最具破坏性的害虫，其捕食性天敌锈褐原花蝽 *Anthocoris minki pistaciae* Wagner 在伊朗阿月浑子树种植区为该害虫的生防因子。本研究在17.5~35℃的8个恒温以及相对湿度55% ±5%，光照周期16L:8D的控制条件下，在*A. pistaciae*若虫上饲养这种捕食性花蝽的同时，调查温度对其发育的影响。结果表明：这种捕食性花蝽在17.5~32℃下可成功发育；然而在35℃下，卵不能孵化，且只有10%的若虫进入成虫阶段。30℃下从卵至成虫羽化的发育历期最短。据测算估计，这种捕食性花蝽的卵、若虫发育以及整个发育(卵至成虫)的积温分别为77，200和263度·日；卵、若虫和整个发育的低温度阈值分别为8.53，9.2和9.47℃。这些结果为建立阿月浑子树木虱的综合防治计划提供了宝贵的信息。

关键词: 锈褐原花蝽；阿月浑子树木虱；发育历期；发育临界低温；阿月浑子树

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